UNITED STATES DEPARTMENT OF AGRICULTURE
RURAL ELECTRIFICATION ADMINISTRATION
WASHINGTON 25, D. C.

January 2, 1952

TELEPHONE ENGINEERING MEMORANDUM 532

Subject: Telephone Engineering and Construction Manual

On January 26, 1951 a limited number of copies of the above manual were distributed under the title Engineering and Construction Manual for REA Telephone Engineers. Copies of this publication are no longer available. The data which were contained in this manual are being revised. These revised sections and new sections will be distributed to system engineers and telephone borrowers as they are completed. This material should be kept in a loose leaf binder and sections no longer in effect should be removed.

Attached are new sections 101, 801, 805, 810, 815, 820, 825 and 830.

Section 101 is a general section giving information on indexing, additions and corrections and the distribution of the various sections of this manual. The remaining sections cover system protection.

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Attachments - 8

OBJECTIVES AND SCOPE OF REA TELEPHONE ENGINEERING AND CONSTRUCTION MANUAL

TABLE OF CONTENTS

1. GENERAL

1.1 The primary purpose of this manual is to provide REA borrowers, consulting engineers, contractors and other interested parties with technical material for use in the design and construction of REA-financed telephone systems.

2. INDEXING

2.1 All of the sections to be issued in the future will be indexed and will be assigned an index number according to the subject covered. All sections will be contained under the following general headings:

Index	General Headings
100-199	General
200-299	System Design
300-399	Central Offices
400-499	Transmission
500-599	Traffic
600-699	Outside Plant
700-799	Subscriber's Station Equipment
800-899	System Protection
900-999	Telephone Carrier and Radio

2.2 Within the above General Headings, index numbers are reserved for appropriate sub-groups. For instance, it should be noted that this section is numbered 101. Section 102 identifies the numerical index; Section 103 the topical index. Sections 104-110 will

deal with the format, indexing and distribution of the manual and 111-199 with general topics in telephony not applicable under other general headings. Similarly, section indexes under general groups 200-900 will be assigned in accordance with the appropriate general heading.

2.3 Each section will be issued with an identifying caption containing index number, issue number and date, in the upper right-hand corner, and an entry identifying the section as a portion of the REA Telephone Engineering and Construction Manual in the upper left-hand corner of the first page. In the upper right-hand corner of all other pages of the section an entry will be made identifying the section in an abbreviated form as a portion of the REA Telephone Engineering and Construction Manual.

Example - First Page:

Rural Electrification Administration	Section 101
Telephone Engineering and Construction Manual	Issue No. 1, December 1951

Example - Other Pages: REA-TE & CM-101

2.4 Each paragraph in each section will also be identified with a number. For example, this is paragraph 2.4 and is the fourth paragraph in a group dealing with the same subject, i.e., indexing of the REA Telephone Engineering and Construction Manual. It should be noted that each paragraph in the group dealing with the subject of indexing has the digit "2" as the whole number and the heading to this group of paragraphs is identified as "2. INDEXING." Similarly, under "1. GENERAL" we find paragraph 1.1 which describes the general purpose of the manual, and under "3. ADDITIONS AND CORRECTIONS" we find paragraphs 3.1 and 3.2 which cover this subject. This practice will be adhered to in the preparation of all sections to be issued in the future.

3. ADDITIONS AND CORRECTIONS

3.1 It is quite obvious that from time to time it will be necessary to make additions and corrections to previously published sections. In many cases these additions and corrections will not be extensive enough to warrent reissuing the entire section. In such cases, the information will be promulgated in an addendum to the main section. Each addendum will be printed on colored paper to permit easy identification, and to insure that it will not be overlooked. It will further be identified as follows:

Example - First Page:

Rural Electrification Administration	Section 101
Telephone Engineering and Construction Manual	Addendum No. 1, December 1951

Example - Other Pages:

REA-TE & CM-101
Addendum No. 1

3.2 The addendum should be filed in front of the section to which it applies and should be referred to whenever the section is used.

4. REPLACING SECTIONS

4.1 When it becomes necessary to replace an entire section, the new one will carry the same caption mentioned under 2.3 with the issue number advanced one number and the new date.

4.2 The opening paragraph of the new section will indicate the data replaced. For instance, referring to the examples in paragraphs 2.3 and 3.1, the replacing section will state, "This section replaces Section 101 Issue No. 1 of May 1951, and Addendum No. 1 of July 1951."

5. DISTRIBUTION

5.1 Future issues of new and revised sections of this manual will be distributed in accordance with mailing lists maintained in REA.

6. INDEXING PREVIOUSLY ISSUED SECTIONS

6.01 Section 102 (numerical index) and Section 103 (topical index) will cover not only those sections being issued from this date on, but also those sections previously issued with the REA memorandum of January 26, 1951.

6.02 In order to make the most efficient use of the manual, it will be necessary that the holders place the proper index number, issue number and date in the upper right-hand corner of the previously issued sections.

6.03 When this is completed, the manual should be assembled with the sections filed in numerical order commencing with 101 (this section) and ending with the highest numbered section issued. To facilitate this, the manual will be printed and punched for a standard three-ring binder.

6.04 That portion of the previously issued manual headed "CONTENTS" and dated January 11, 1951, should be removed.

6.05 The chapter entitled, "SUMMARY OF OBJECTIVES AND REQUIREMENTS IN THE SYSTEM AND PLANT DESIGN," should be indexed as 201, Issue No. 1, January 1951.

6.06 The second chapter, "COMMUNICATION WIRE - FIELD ENGINEERING AND CONSTRUCTION," will be section 614, Issue No. 1, January 1951.

6.07 The third chapter, "FIELD ENGINEERING AND CONSTRUCTION OF WOOD POLE LINES," will be section 609, Issue No. 1, January 1951.

6.08 The fourth chapter, "GUYS AND ANCHORS ON WIRE AND CABLE LINES," will be section 650, Issue No. 1, January 1951.

6.09 The fifth chapter, "CROSSINGS OF COMMUNICATION WIRES AND CABLE UNDER POWER DISTRIBUTION AND TRANSMISSION LINES," will be section 604, Issue No. 1, January 1951.

6.10 The sixth chapter, "GROUND, ROAD, AND RAIL CLEARANCES FOR AERIAL WIRE AND CABLE," will be section 605, Issue No. 1, January 1951.

6.11 The seventh chapter, "CLEARANCES AND SEPARATIONS BETWEEN ELECTRICAL SUPPLY CONDUCTORS AND TELEPHONE WIRES AND CABLES (JOINT USE)," will be section 691, Issue No. 1, January 1951.

6.12 The eighth chapter, "STAKING TABLES FOR JOINT USE AND THEIR APPLICATION TO SPECIFIC PROBLEMS," will be section 692, Issue No. 1, January 1951.

6.13 The ninth chapter, "REHABILITATION OF EXISTING PLANT AS PART OF A NEW SYSTEM," will be section 215, Issue No. 1, January 1951.

<u>Index</u>

Manual, Objectives and Scope

CONDITIONS REQUIRING ELECTRICAL PROTECTION

CONTENTS

1. GENERAL

1.1 Telephone systems are subject to disturbances from external sources of electrical energy. These sources include electric supply circuits and natural phenomena, such as lightning or low energy static effects. The effects in the telephone plant may be confined to interference with its operation, as in the case of noise, or they may be capable of creating hazards to subscribers, personnel and plant. Sections 801 - 830 consider the effects of accidental contacts between electric supply circuits and telephone circuits, low frequency electric and magnetic induction from electric supply circuits, and natural phenomena.

1.2 As will appear in subsequent sections, some protection measures are intended to be effective both against lightning and certain types of disturbances from electric supply systems. Others are meant to avoid or minimize trouble either from lightning alone, or from one or more kinds of disturbances from electric systems.

1.3 Protection equipment, in general, should possess sufficient sensitivity so that it will operate before the telephone plant is damaged but, at the same time, it should not be so sensitive as to cause undue service interruptions. It would not be economical to install and maintain protection equipment to prevent all damage to which plant is liable. Hence, even with a properly designed protection system, some damage may be expected when unusually severe disturbances occur.

1.4 Prior to considering protective measures for use on a particular telephone system, the engineer should familiarize himself with the various types of protective devices described in these sections in order to determine which devices to utilize for meeting usual and unusual conditions.

2. LIGHTNING DISTURBANCES

2.1 In many areas of the United States lightning is one of the chief sources of disturbance. Its frequency of occurrence and severity vary considerably throughout the country, with some areas being subjected to frequent and severe storms, while other areas are subjected only to infrequent disturbances.

2.2 Peak lightning stroke currents ranging from several thousand amperes to 200,000 amperes or more have been recorded, while approximately fifty percent of the strokes have currents exceeding 25,000 amperes. The current in a single lightning stroke may have a duration ranging from 40 or fewer microseconds up to several hundred microseconds. Many lightning "flashes" are of a multiple stroke character, with a total duration of a millisecond or longer.

2.3 The electrical resistivity* (or specific resistance) of the earth is a factor of almost as much importance as the intensity and the frequency of occurrence of lightning strokes in determining the damage which lightning may cause in a given locality. The intensity (number of amperes) of a stroke is affected in only a very minor way by the earth resistivity. Hence, if the resistivity is high, the voltage which the stroke may build up across a dielectric and the distance that lightning current may travel along a conductor before attenuating to harmless values are both greater than if the resistivity is low. The result of this is that liability to lightning damage is greater in some parts of the country with high earth resistivity and only moderate lightning severity than it is in other parts with low resistivity and greater lightning severity.

2.4 The earth resistivity varies over a considerable range in the continental United States, from a few meter-ohms along part of the coast of the Gulf of Mexico to 10,000 meter-ohms or more in upland or mountainous country.

2.5 Fig. 1 has been prepared as a tentative guide for use in deciding whether lightning trouble beyond the ordinary may be expected unless additional measures of prevention are taken. In this figure, both

* The practical unit of electrical resistivity, the meter-ohm, is defined as the resistance in ohms between opposite faces of a cube of earth whose volume is one cubic meter.

lightning severity and earth resistivity are taken into account. The areas where unusual amounts of lightning damage may be expected are shaded. The data are incomplete, particularly for the northern tier of states from the Pacific Coast to Lake Superior, the belt through Arizona, Utah, Idaho, Central and Southern Texas, except the Gulf Coast, and northern New England. It should not be assumed that lightning interference will be of insignificant character in a given locality merely because the locality is not shaded in Fig. 1. Local experience, including experience of REA electric cooperatives, may reveal that a particular area is subject to severe lightning disturbances, therefore this local experience should be accepted as a guide in determining measures of protection.

2.6 Lightning produces voltages on conductors by direct strokes, by conduction through the earth or over other conductors, or by induction. Direct strokes may be very destructive, but conduction or induction effects of varying severity are more frequent and can produce hazards and damage to plant.

2.7 Electric supply lines which cross over or are in conflict with telephone lines may produce hazards and damage to telephone plant by means of a "follow-up" power arc between the lines. High voltage due to lightning on the electric supply lines may produce ionization of the air which may result in the establishment of an arc between the electric lines and adjacent telephone lines. Once this arc is established it may be sustained by the electric circuit voltage even after the lightning disturbance has disappeared. An arc of this type, remaining even for a short time interval, may result in considerable damage to telephone plant if adequate clearances between the lines are not maintained.

2.8 Some of the types of damage resulting from lightning are fires at subscriber stations and central offices, fusing or severing of conductors, shattering of poles and insulators, and dielectric failures in cables.

3. POWER CONTACTS

3.1 The possibility of damage to telephone systems due to accidental contacts between electric supply lines and telephone lines is one of the most important situations requiring protection measures. The most common causes of these power contacts are falling tree limbs, improper sagging of conductors, damaging acts by the public, structural failures, poor maintenance, sleet and wind storms, and conductor failure due to burns from lightning. The contacts may occur at crossings, underbuilds, joint use arrangements, and where electric supply and telephone lines are paralleled with inadequate separation after construction.

3.2 In joint use arrangements, a power conductor failure would probably result in contact with multi-circuit open wire telephone construction, but where the telephone circuits consist only of aerial cable, a single circuit of open wire, or drop wire, the probability of contact is lessened. Should contact occur, however, the value of the voltage impressed upon the telephone system depends primarily upon the voltage to ground of the power system at the point of contact and the resultant impedance of the several paths to ground from this point.

3.3 If possible, crossovers should take place at a common pole instead of in the span in order to reduce the probability of contact. Where joint use arrangements are properly constructed and maintained, and provided with adequate right-of-way clearance, accidental contacts seldom occur. Underbuilds or parallels with inadequate separation should be avoided.

4. LOW FREQUENCY ELECTRIC* INDUCTION

4.1 When telephone circuits are in close proximity to alternating current power lines a voltage (which is sometimes called an electrostatic voltage) is induced upon the telephone wires from the electric fields surrounding the power conductors; these fields being due, in turn, to electric charges on the power wires. Under normal conditions, the induced voltage on the telephone circuit is usually limited due to drainage provided by cable capacitance and the central office line termination. In the event, however, that open wire circuits are disconnected from the cable or central office for any reason, and also where the open wire lines are long, the induced voltage on these open wire circuits may require reduction. In some instances, its open-circuit value may be as much as 700 or 800 volts above ground. The possibility of injury to persons, - linemen, particularly - in contact with the wire subject to this induced voltage does not depend upon the open-circuit voltage, but upon the current drawn through the contact. This current is so small (due primarily to the poor regulation characteristics of the capacitive coupling between the power and telephone wires) that no serious hazard from electric shock as such is to be expected. Nevertheless, the shock, though mild in intensity, may have a surprise effect involving hazard to a man working on a pole. This induced voltage may also damage station ringers and cause bell tapping.

4.2 All disconnected open wire circuits should therefore be grounded at the cable terminals or at the central office if no cable is used.

*Though the relations depend upon electrostatic principles, the term "electrostatic" is not appropriate for this situation due to the varying field considered.

5. LOW FREQUENCY MAGNETIC INDUCTION

5.1 When a phase wire of a grounded-neutral power line is accidentally grounded, current flows from the source of power to the point where the accidental ground occurs. A similar situation arises if two phase wires of an isolated neutral system become grounded at separate points. This fault current, in either case, increases the magnetic field about the power lines involved, and the increased magnetic field, in turn, increases the induced voltage in paralleling telephone circuits. The magnitude of the induced voltage is proportional to the fault current and the degree of coupling involved. If a long parallel at close separation exists between the power and telephone lines, the coupling effect is relatively high. If, in addition, the fault current is high, the induced voltage may be of sufficient magnitude to be dangerous to linemen working on the line, to subscribers, or to the public, and it may also produce hazards such as acoustic shock to operators and damage to plant. Because of the above effects, long parallels with power lines having high fault currents should be avoided or kept to a minimum but, if unavoidable, suitable protective measures should be provided.

5.2 The possibility of high induced voltage may require special protective devices and should be given special study in cases of unusually long sections of joint use construction, especially if the power system operating voltage is above 8700 volts to ground.

6. RISE IN GROUND POTENTIAL

6.1 When telephone circuits are installed in power stations or power substations, additional precautionary measures must usually be taken to guard against high ground potentials. These potentials are the result of high fault currents flowing through the resistance of the power station ground when accidental electric circuit grounds occur, particularly in the immediate vicinity of the station. Even though the ground resistance of the power station is low, the fault current may be of sufficient magnitude to increase the ground potential in the immediate area to a value sufficient for telephone station protector operation. The high ground potential impressed on the ground side of the protector blocks may result in breakdown of the blocks, thus impressing this high ground potential upon the telephone circuits leading from the power plant. Special protective devices must therefore be provided to alleviate this hazardous condition.

7. DESCRIPTION OF USUAL AND UNUSUAL SITUATIONS

7.1 For convenience in discussing system protection, situations involving telephone plant are divided into two categories - usual situations and unusual situations. Usual situations are those situations where readily available devices can be employed to provide system protection without the situation being given special study by the borrower's

Engineer. Unusual situations are those situations where conventional devices are not suitable to provide adequate system protection and special studies by the borrower's Engineer will be required to determine the system protection scheme.

7.2 The tabulation below delineates in a general way between the two types of situations. It should be borne in mind that the circumstances in any given situation may not fall entirely within either of these general classifications. The Engineer should be alert to such possibilities and use the protection scheme which is appropriate to the specific situation.

Usual Situations	Unusual Situations
1. Predominantly aerial plant.	1. Predominantly underground plant.
2. Medium or low lightning incidence with medium or low earth resistivity.	2. High lightning incidence with high earth resistivity.
3. Exposure to contacts with electric supply systems with operating voltages not exceeding 15,000 volts to ground.	3. Exposure to contacts with electric supply systems with operating voltages exceeding 15,000 volts to ground.
4. Joint use with electric supply systems of the non-multi-grounded neutral type with circuit voltages not exceeding 5000 volts.	4. Joint use with electric supply systems of the non-multi-grounded neutral type with circuit voltages exceeding 5000 volts.
5. Joint use with electric supply systems of the common multi-grounded neutral type* with operating voltages not exceeding 8700 volts to ground.	5. Joint use with electric supply systems of the common multi-grounded neutral type* with operating voltage exceeding 8700 volts to ground.
6. No long parallels at close separation with electric supply system circuits with operating voltages in excess of 25,000 volts to ground.	6. Long parallels at close separation with electric supply system circuits with operating voltages in excess of 25,000 volts to ground.
	7. Telephone stations installed in power stations or substations.

* A common multi-grounded neutral electric supply system is one which has solid interconnected primary and secondary neutrals in addition to the prescribed number of ground connections.

Sections 805 through 820 hereinafter discuss telephone system protection for usual situations. Fig. 2 shows a typical over-all protection scheme applicable to usual situations encountered in system protection. The various types of protection equipment discussed in Sections 805 through 820 are included in this scheme.

7.3 Section 825 briefly discusses unusual situations and several possible measures that can be employed where such situations arise.

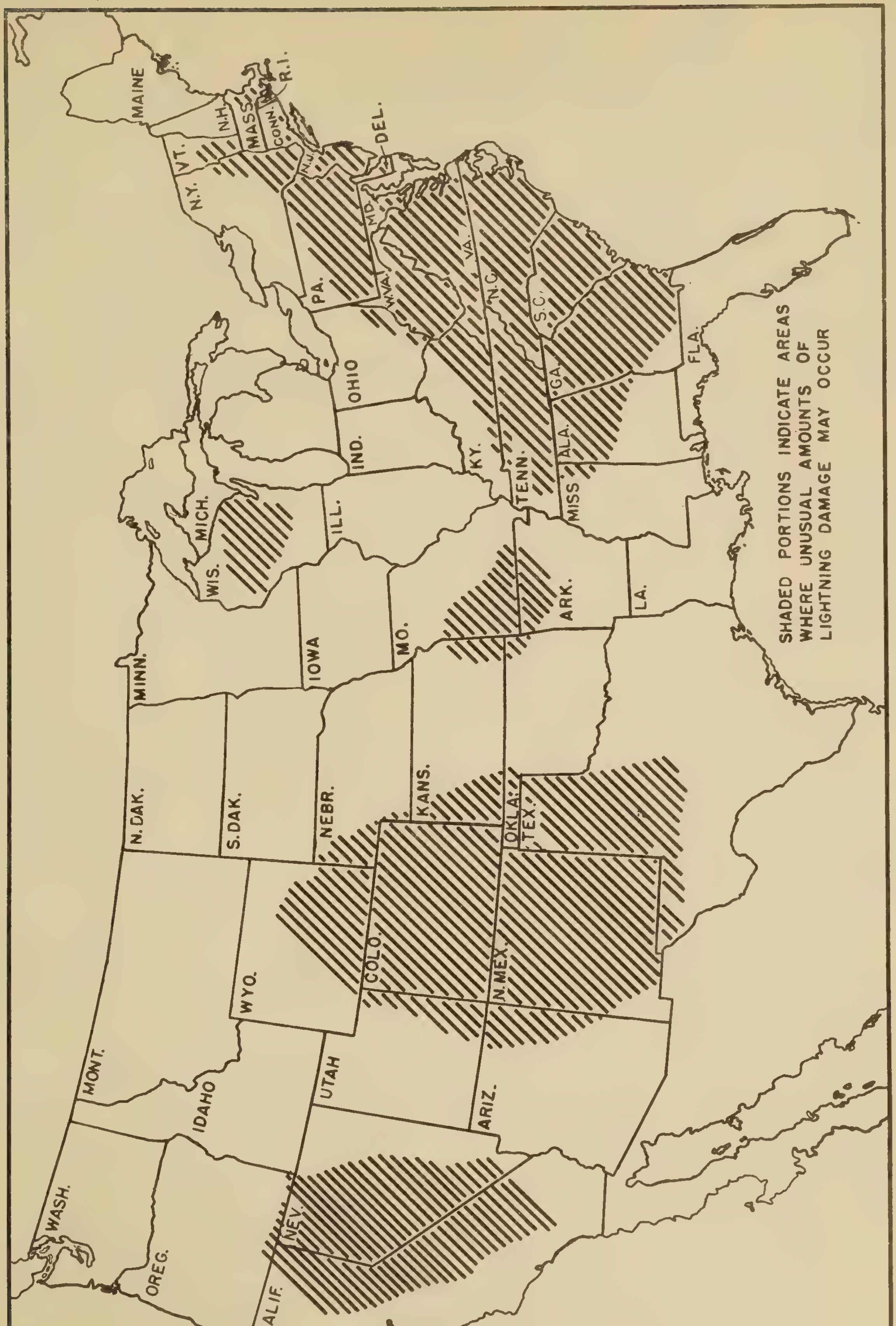
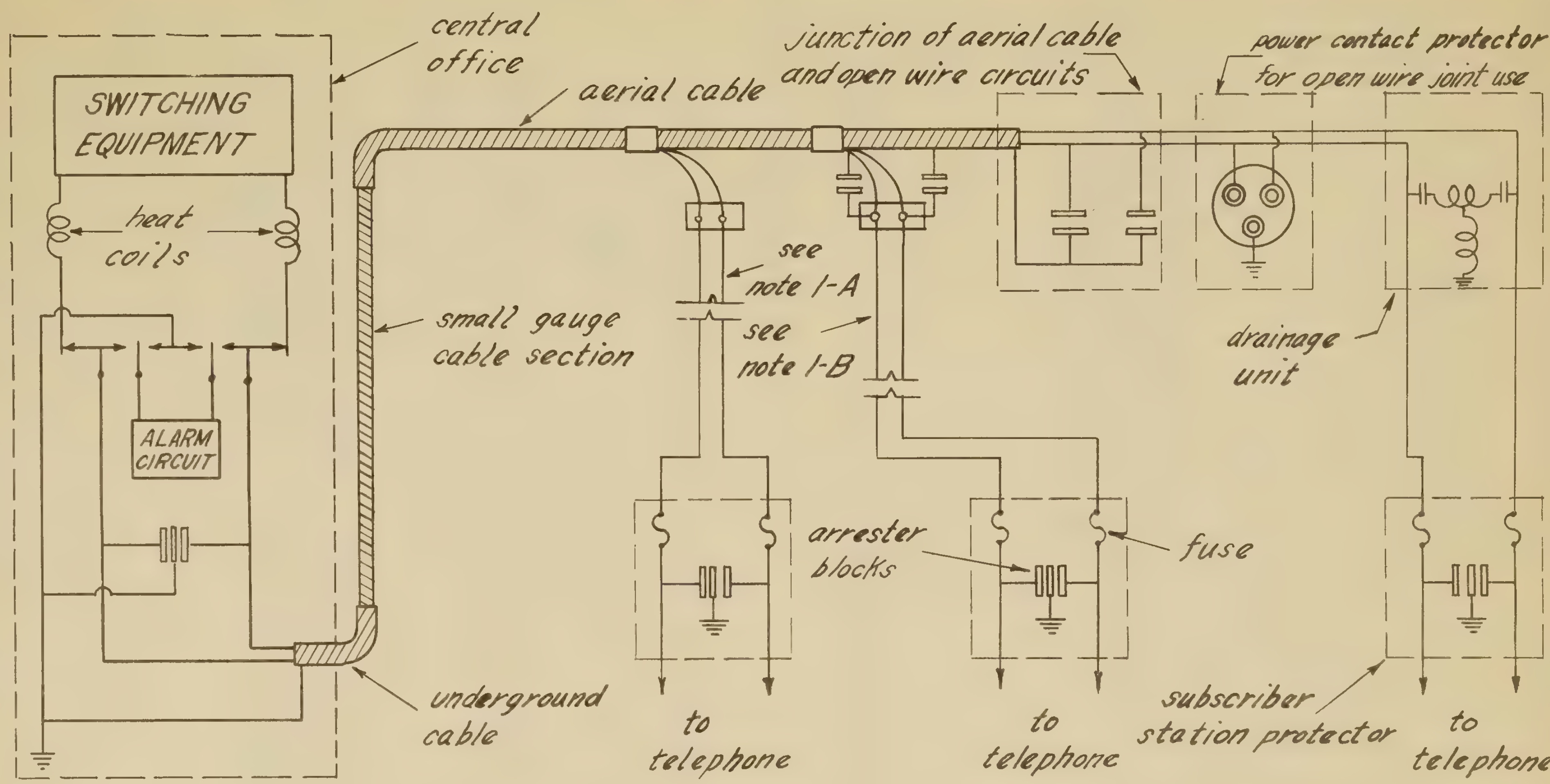

SHADED PORTIONS INDICATE AREAS
WHERE UNUSUAL AMOUNTS OF
LIGHTNING DAMAGE MAY OCCUR
MAINE
N.H.
VT.
MASS.
R.I.
CONN.
N.Y.
N.J.
DEL.
MD.
PA.
W.VA.
VA.
N.C.
S.C.
GA.
FLA.
OHIO
IND.
KY.
TENN.
ALA.
MISS.
MICH.
ILL.
WIS.
MINN.
IOWA
MO.
ARK.
LA.
N.DAK.
S.DAK.
NEBR.
KANS.
OKLA.
TEX.
WYO.
COLO.
N.MEX.
MONT.
IDAHO
UTAH
ARIZ.
WASH.
OREG.
NEV.
CALIF.

Fig. 1



Note:
1. Open wire, buried wire or drop wire extension:
A. Less than 1500 ft. from cable terminal.
B. More than 1500 ft. from cable terminal.

Fig. 2 Usual Protection Scheme.

SUBSCRIBER STATION PROTECTION

CONTENTS

1. GENERAL

1.1 This section describes the subscriber station protector, its installation, and the grounding methods to be used at the telephone station.

2. SUBSCRIBER STATION PROTECTOR

2.1 The subscriber station protector, Fig. 1, is designed to protect telephone stations from excessive voltages which may appear between either conductor and ground, and sustained overcurrents. The voltage limiting device is usually an air gap lightning arrester connected between each side of the line and ground, while the current limiting device is a fuse inserted in each side of the line.

2.2 The lightning arresters connected on the subscribers' side of the line, as shown in Fig. 1, should operate on any voltage exceeding 450 to 620 volts peak, whether it is due to lightning or other causes.

2.3 The fuses are designed to operate on power currents exceeding their rating, but are not designed to operate on lightning surges, although they frequently do so. The fuses should be seven ampere power rated, and provide reliable clearing of currents at unity power factor with values up to 300 amperes at 3000 volts, 60 cycles, r.m.s., across their terminals.

2.4 The fuses and lightning arresters are mounted on an insulated base which also provides a means for terminating the wiring. The complete assembly is provided with a mounting bracket, or the equivalent, and a weatherproof cover to make it suitable for outdoor installation. The description given in the above paragraphs is in accordance with the REA Specification for Fused Type Telephone Station Protectors.

2.5 The use of an approved type fuseless telephone station protector has been permitted by an interim amendment to Section 8011.d of the National Electrical Code. (See 1951 Edition.) This type of protector can be used in situations where insulated conductors are used to extend telephone circuits to a building from a cable having a grounded metal sheath. However, a protector for this purpose must be approved by the Underwriters' Laboratories, Inc. Such a protector is not generally available as yet to the independent telephone industry.

3. SUBSCRIBER STATION PROTECTOR INSTALLATION

3.1 An outdoor type subscriber station protector should be installed at the subscriber end of each drop wire. The outdoor installation provides ease in replacing fuses or cleaning arrester blocks, and it reduces fire hazard should high voltages cause arcing across the fuse terminals. The protector must conform with REA specifications regarding installation, and its ground terminal should be connected to a low resistance ground. The ground resistance should be as low as practicable but, in general, 25 ohms or less is sufficient.

4. SUBSCRIBER STATION PROTECTOR GROUNDING METHODS

4.1 The primary objective of protective devices installed at a subscriber's station is to prevent telephone users and the subscriber's premises from being subjected to differences of potential of sufficient magnitude to create hazards. These differences of potential may result from abnormal conditions on the telephone system, the electric supply system, or other sources. Differences of potential between telephone and electric supply systems within the subscriber's premises can be avoided or minimized by bonding the telephone protector ground to the electric supply system ground and to any extensive water or gas piping systems which are available on the premises.

4.2 The preferred telephone service ground is obtained by connecting the telephone protector ground lead to the ground electrode of the common multi-grounded neutral of the electric supply system if such a system serves the premises. This grounding scheme should be used in situations where a driven ground rod is used for the common multi-grounded neutral electric supply ground and in situations where the common multi-grounded neutral electric supply ground

is bonded to an extensive underground water or gas system at the premises. For either situation, no separate telephone ground electrode is necessary.

4.3 Where the electric supply system at the premises is other than the common multi-grounded neutral type a telephone ground electrode separate from the electric supply ground electrode should be used unless the electric supply and telephone systems are grounded to the same extensive underground water or gas piping system at the premises. Where the underground piping system does not exist the separate telephone ground electrode and electric supply ground electrode should be bonded with a No. 14 AWG copper wire, or a wire of equivalent conductivity.

4.4 The following telephone system grounds, listed in the order of preference. should be used where a separate ground electrode is necessary and in instances where no electric supply system exists at the premises:

(a) Public water systems.
(b) Extensive underground gas systems.*
(c) Private water systems having at least 10 feet of buried pipe in moist earth at a depth where it will not freeze, or a steel well casing.
(d) Grounded metallic structures of a permanent nature, such as buildings.
(e) Ground rods.

There may be situations where (d) would be preferable to (c) because it would provide a lower resistance ground.

4.5 Steam pipes, hot water pipes, and lightning rod conductors should not be used as grounding electrodes for telephone station protectors.

4.6 Under some circumstances the bonding of the telephone and electric supply ground electrodes introduces a hazard to telephone plant which would be reduced or avoided if separate grounds were used, but such circumstances are rare and the improved security from excessive potential differences at the subscribers' premises must be accepted as the ruling consideration.

5. USE OF GROUND RODS

5.1 A ground obtained by means of a driven rod usually has a resistance in excess of 25 ohms (depending upon earth resistivity); therefore it should be used only if no other suitable means of grounding is available.

* The ground connection to a gas system must be made between the meter and the main.

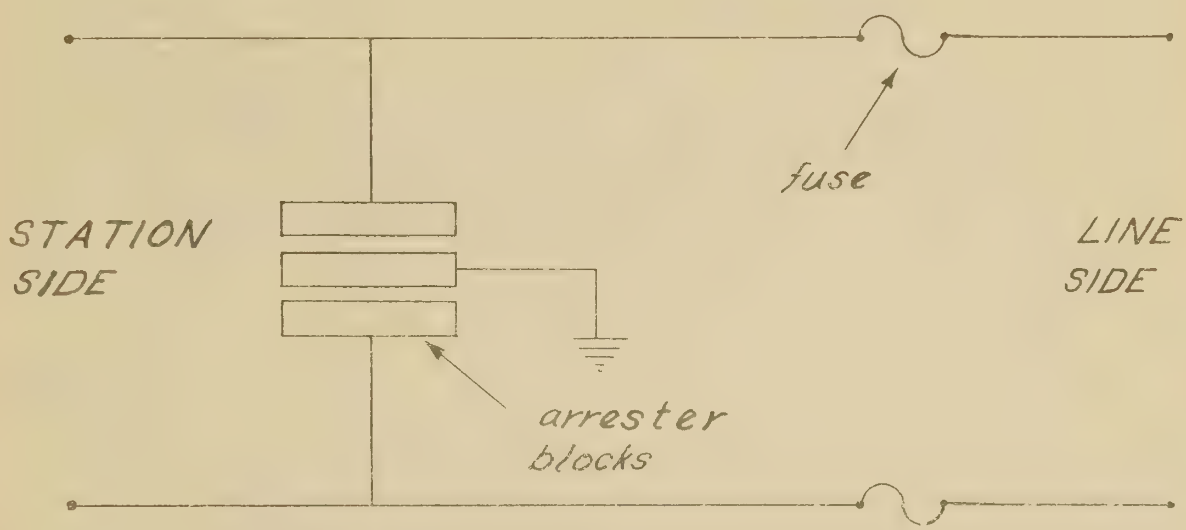


Fig. 1 Subscriber Station Protector.

CENTRAL OFFICE PROTECTION

CONTENTS

1. GENERAL

1.1 This section describes heat coils, protector blocks, small gauge cable sections for use as fuse protection at central offices, and central office grounding methods. These devices are used for protecting central office equipment from abnormal voltages and currents.

2. HEAT COILS

2.1 Heat coils are designed to protect central office apparatus from damage due to small foreign currents in telephone circuits. These currents, called "sneak currents," are of such magnitude that they will not operate fuses, and the resultant voltage across the circuit is not sufficient to operate air gap arrester blocks. However, if these currents are allowed to persist for sufficient time they can overheat the central office equipment connected to faulted lines, resulting in considerable damage.

2.2 Heat coils are constructed from resistance wire in such a manner that the heat created from the sneak currents melts a soldered connection which, in turn, releases a line grounding spring. The circuit carrying the sneak current is thereby grounded to the mainframe ground strip. Some types of heat coil assemblies, upon operation, both ground the outside circuit and disconnect the central office equipment associated with this circuit. One representative type of heat coil will carry 0.35 ampere for three hours, but will operate if a current of approximately 0.5 ampere flows for 3.5 minutes; while

lower value sneak currents require a longer period of time before operating the coils. Momentary surges of current are not effective in producing coil operation, however.

3. PROTECTOR BLOCKS

3.1 Carbon block protectors should be used to prevent high voltage from damaging central office equipment. These protectors provide a low resistance discharge path to ground, and they should have the same breakdown voltage as the blocks used at subscribers' stations. (Section 805, Paragraph 2.2)

4. INSTALLATION OF HEAT COILS AND PROTECTOR BLOCKS

4.1 Heat coils and protector blocks, Fig. 1, should be mounted in the protector groups and installed on the vertical side of the main distributing frame in the central office. In addition to their protection function, the protector groups provide a convenient means for testing outside lines and switchboard circuits. For "A" type main distributing frames, the non-working pairs should be bunched and grounded while for "B" type main frames the non-working pairs are protected by the carbon blocks.

5. SMALL GAUGE CABLE SECTIONS AND THEIR INSTALLATION

5.1 Small gauge cable sections should be used to provide fuse protection for the central office. The conductors of these small gauge cable sections have sufficient impedance to limit currents on the telephone wires in the event of a power contact, and their use saves appreciable fuse maintenance while reducing mainframe costs.

5.2 The small gauge cable section should be made up of wires 24 gauge or smaller with a length of at least six feet. Only under unusual conditions will the current due to a power contact be of sufficient magnitude to cause fusing of the wires in this cable section. The individual mainframe protector springs can safely carry currents up to the fusing point of these wires.

5.3 Experience has shown that the use of the small gauge cable section for fuse protection does <u>not</u> increase the number of cable troubles.

5.4 Small gauge cable sections should be installed at the junction of underground or buried cable from the central office with aerial cable, open wire, or other lines exposed to power contacts. Installations should be made at or near the pole or poles used to make extensions of the underground or buried cable from the central office. Where the central office is entered through aerial cable, the small gauge cable section may be placed at the office end or near it.

5.5 If 24 gauge or smaller cable is used for entrance cable, no additional small gauge cable section is needed in the protection scheme.

6. CENTRAL OFFICE GROUNDING METHODS

6.1 A central office ground resistance of five ohms or less is desirable for protecting central office equipment as well as providing for proper operation of the telephone system.

6.2 The preferred central office ground is the common multi-grounded neutral of the electric supply system together with auxiliary driven ground electrodes interconnected to it at the central office. The installation of these ground electrodes is discussed in Section 810, Paragraphs 7.1 - 7.5.

6.3 Public water systems and public gas systems also normally provide a low resistance ground. Auxiliary driven ground electrodes should also be interconnected to these systems at the central office.

Prior to connecting to piping systems, however, the Engineer should consult with the local officials of the water or gas systems regarding the installation. Where public water systems are used in the grounding scheme a No. 6 AWG copper wire, or a wire of equivalent conductivity, should be used for bonding around meters and any other submains that could become physically disconnected and thereby jeopardize the ground connection. Ground connections to public gas systems should always be made between the meter and the main.

6.4 Steam pipes, hot water pipes, and lightning rod conductors should not be used as grounding electrodes for central offices.

6.5 Where the electric supply system at the central office is other than the common multi-grounded neutral type the auxiliary driven ground electrodes (Paragraph 7) must be bonded to the ground electrode of the electric supply system by means of a No. 6 AWG copper wire, or a wire with equivalent conductivity and resistance to corrosion unless the separate ground electrodes are interconnected by a water or gas piping system at the premises. A single jointly used driven ground electrode for the central office and the electric supply circuit should never be used.

7. AUXILIARY DRIVEN GROUND ELECTRODES

7.1 In many rural areas the community dial office will be of the unattended type with no available ground connection to water or gas systems. In most instances, however, an adequate central office ground can be obtained by means of the common multi-grounded neutral of the electric supply system serving the central office together with auxiliary driven rods or pipes of sufficient length to reach permanently moist earth, or

by means of the auxiliary driven ground electrodes if the electric supply system is other than the multi-grounded neutral type.

7.2 Ground rods or pipes should be driven into the earth parallel to each other at intervals of at least six feet, depending upon the length of rod. The size of the central office, the value of earth resistivity in the vicinity, and the texture, moisture, and chemical content of the soil will determine the number and type of ground rods or pipes required. Several typical installations are given below for situations where good soil conditions are present. However, the Borrower's Engineer should consider other types of installations in areas where corrosion is a problem or the earth resistivity is unusually high.

(a) For an ultimate capacity of 200 or more lines and trunks, five 3/4 inch by 10 feet galvanized iron pipes should be used.

(b) Where the ultimate capacity ranges from 100 to 200 lines or trunks, five 1/2 inch by 8 feet copper covered steel ground rods should be used.

(c) For ultimate capacities up to 100 lines, three 1/2 inch by 8 feet copper covered steel ground rods should be used.

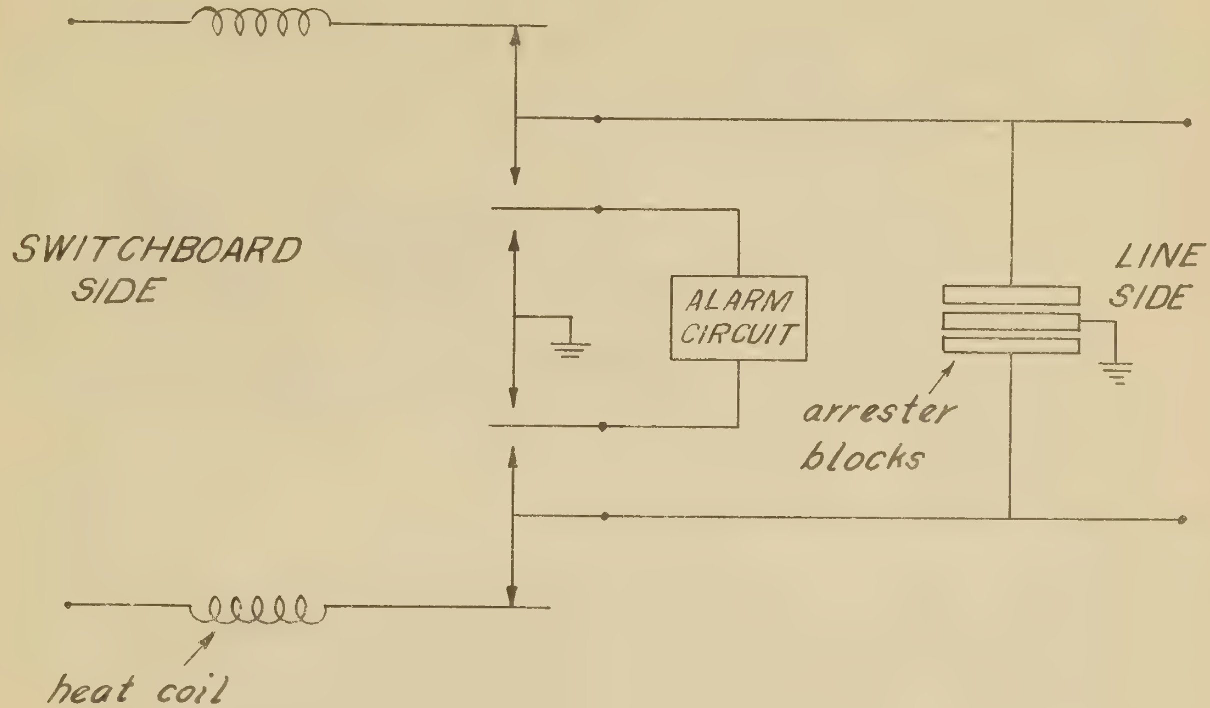
7.3 A No. 6 AWG bare copper wire, or one of equivalent conductivity and resistance to corrosion should be used for connecting the electrodes to each other and to the ground bus on the main distributing frame. Connections should be made by means of soldered joints, solderless connectors, or sleeves. The ground wire should have a minimum number of bends and as direct a run from electrodes to the ground bus as possible. For outdoor installations this ground system should be located at least two feet from a side of the exchange building and the ground wire should connect to the electrodes in a trench at a depth of at least one foot. All connections below the ground level should be coated with asphaltum paint and wrapped in layers of muslin saturated with this paint. The connections should not be covered with soil until the paint has dried thoroughly. Ground leads should be carried through the wall of the exchange building by means of a conduit and at a location determined by the Engineer.

7.4 If the central office building has a basement the grounding system should be installed in the basement directly under the main distributing frame if practicable. All ground leads, including the conductor which interconnects the grounding electrodes, should be above the floor level to facilitate inspection, but should be provided with adequate mechanical protection.

7.5 Switchboards, cable sheaths, grounded ringing terminals, power conduits and cables, relay rack frames, and auxiliary equipment requiring grounding should be connected to the main distributing frame

ground bus or directly to the ground electrode lead, whichever is the most economical for the central office layout. Manufacturers' recommendations as to ground wire types and sizes for their equipment should be followed.

7.6 The protective equipment on the main frame is usually connected to the main frame bus bar with a No. 6 AWG copper wire by means of a compression type terminal lug. The ground wire is also connected to this bus bar by means of a compression-type terminal lug.



Note:
Upon operation of a heat coil this circuit grounds the faulted circuit, disconnects it from the central office equipment, and sounds an alarm circuit.

Fig. 1 Typical Central Office Protector.

CABLE CIRCUIT PROTECTION

CONTENTS

1. GENERAL

1.1 This section describes methods for protecting cable circuits from lightning and power contacts by means of arrester blocks, sheath grounding, and sheath bonding. In the case of non-metallic cable sheaths which are provided with metallic shields, the sheath grounding and bonding referred to hereinafter means the metallic shield.

2. GROUNDING OF CABLE SHEATHS

2.1 Aerial cable sheaths of short length may be effectively grounded at the end nearer the central office by being electrically continuous with underground sheaths connected to the central office ground bus bar. If no underground cable exists, or only a short length, the aerial cable sheath must be effectively grounded at or near the central office by connection to the central office ground, or by other means. Uninsulated guy wires bonded to the sheath provide a leakage path to ground but unless frequently installed they are not normally considered as being adequate for effective grounding.

2.2 The aerial cable sheath should also be grounded at the open wire end of the cable run if a local ground having a resistance of the same order of magnitude as the cable sheath resistance to ground from this point, or preferably lower, is readily available. In most cases it is not practicable to follow this grounding procedure unless the common multi-grounded neutral from an electric supply system is readily available.

2.3 In some instances, particularly in areas of high lightning incidence, it may be desirable to install air gap lightning arrester blocks on the open wire circuits within one-half mile of the cable junction to which they are connected. An installation of this type reduces the effect of the lightning surges which reach the cable plant. The lightning arresters should be connected to ground by means of a driven ground rod or, in some situations, it may be desirable to incur the expense of obtaining a low resistance ground. This type of protection scheme should not be used unless a careful study by the Borrower's Engineer indicates that it is necessary. However, if power contact protectors (Section 820 Paragraphs 3 - 4) are installed within one-half mile of the cable terminal in either a joint use arrangement or a joint pole crossing the lightning arrester blocks should not be installed as the power contact protectors provide some degree of lightning protection.

2.4 The use of chemically treated grounds, installation of counterpoises, or other special devices for protective schemes should not be attempted unless a careful study by the Borrower's Engineer indicates that they are necessary in a particular situation.

2.5 The grounding of cable sheaths discussed in the foregoing paragraphs may at times conflict with arrangements desired for corrosion prevention. In such cases, the procedure to be used should be determined by the Borrower's Engineer after a thorough study of all the factors involved in the problem.

3. BONDING OF CABLE SHEATHS

3.1 Bonding of cable sheaths to suspension strands and the bonding of sheaths to each other in parallel cable runs reduces potential differences resulting from power contacts or lightning by providing increased conductivity for any foreign currents which may reach the cable sheaths.

3.2 The bonding of metallic aerial cable sheath to the suspension strand in lashed cable is not usually necessary due to the intimate contact between them.

3.3 If ring supported cable is being retained in the telephone plant, adequate bonding is usually provided by means of grade clamps or tinned copper bonding ribbons. If bonding ribbons are used, they should be installed at the beginning and end of the cable installation, and at every tenth pole in long cable runs.

3.4 If more than one ring type or lashed type cable is attached to the same pole by means of separate through-bolts, the sheaths and suspension strands of the various cables should be bonded together at the beginning and end of the multi-cable installation and at approximately each tenth pole in long multi-cable runs.

3.5 Where non-metallic sheath cable is used, the connection made between the strand and lead sleeve by the lashed cable supports provides the required bonding.

3.6 Underground cables with metallic sheaths in the same duct run should have their sheaths bonded together by means of tinned copper bonding ribbons at every manhole. This decreases any tendency for arcing and resultant underground explosions. Where underground cables have no connection with aerial wires the shielding is such that no protective device except sheath bonding is normally employed.

3.7 All cables entering a central office, whether aerial or underground, must have their sheaths bonded to each other with bonding ribbons inside the central office and the bonded cable sheaths should be connected to the central office ground bus bar.

4. PROTECTION IN JOINT USE ARRANGEMENTS

4.1 Where telephone cables are attached to the same poles used for electric supply circuits of the multi-grounded neutral type whose voltages are less than 8700 volts to ground the cable sheaths and strands should be bonded to the vertical ground wire on the pole if this ground wire is connected to the neutral wire. This bonding connection should be made at the poles where the joint use arrangement begins and ends, even though the joint use arrangement may only involve several spans. If, in addition, the cable diameter is small and the joint use arrangement is longer than 1.5 miles additional bonds should be placed in a similar manner at intervals not exceeding one mile.

4.2 The bonding to the vertical ground wire connected to the common multi-grounded neutral may be made by an individual representing the construction contractor or the telephone system. Direct connection to the neutral wire should be made only by a representative of the electric system.

4.3 In most instances, bonding of the telephone cable sheath to the multi-grounded neutral will result in a decrease in noise level of the telephone system; but if the noise level should increase, the Borrower's Engineer should make a thorough study of the situation to determine mitigative measures. The noise level could increase if a high residual current should get on the multi-grounded neutral and the cable sheath (due to bonding). This would result in induced voltages from the cable sheath to the conductors inside the cable. The residual current could be high on a long single phase tap from a three-phase system, but a well balanced three-phase system has little residual current flow.

4.4 Where telephone cables are attached to the same poles used for electric supply circuits of the non-multi-grounded neutral type, the cable sheaths are grounded only by means of their connection to the central office ground provided the sheath is electrically continuous. The sheath should be electrically continuous unless it would conflict with arrangements desired for corrosion prevention, as mentioned previously.

5. PROTECTION AT CROSSINGS

5.1 Where telephone cables cross a multi-grounded neutral electric supply circuit (whose voltage is less than 8700 volts to ground) at a jointly used pole, the sheath and suspension strand should be bonded to the vertical ground wire on the pole if this ground wire is connected to the neutral wire. The bonding to the ground wire may be made by an individual representing the construction contractor or the telephone system. Wherever possible, crossings should be made on a jointly used pole. For telephone cable circuits crossing electric supply circuits within a span and crossings involving circuits whose voltages are above 8700 volts to ground no comparatively effective protective arrangements are available and it will be necessary to continue to rely on adequate construction of the crossings.

5.2 Where crossings are made by means of underground cable dips in open wire leads, lightning protection must be provided at both cable terminals. Lightning arrester assemblies (Section 815 Paragraphs 6.2 - 6.3) should be used in conjunction with a suitable ground for this type of installation. If the cable has a metallic sheath it should be included as part of the ground connection. Local grounds of low resistance are desirable on installations of this type.

5.3 Where crossings are made by means of underground cable dips in aerial cable circuits no lightning protection is needed at the crossings unless circuits of the non-cable type enter the aerial cable at the crossing.

6. PROTECTED AERIAL CABLE TERMINALS

6.1 Protected aerial cable terminals should be used to prevent damage to cables from lightning which may be impressed on cable pairs extended by open wire, buried wire, drop wire, or outside distributing wire. By protecting those pairs extended from the cable the maximum potential differences within the cable are considerably reduced. This prevents cable dielectric failure with its consequent conductor troubles.

6.2 The preferred type of protected aerial cable terminal is one containing air gap lightning arresters and binding posts as an integral

part of the distribution terminal. Fuses are not included in a terminal of this type because fuse protection for the central office is available by means of the small gauge cable section described in Section 810 Paragraph 5. Fuses should not be used as a cable protective device.

6.3 One or five pair lightning arrester assemblies can be used for protection of aerial cable. These devices consist of air gap arrester blocks, a ground plate and connection lug, an insulating base and a weatherproof metallic enclosure and mounting. These assemblies can be used in conjunction with unprotected aerial cable terminals to form the electrical equivalent of the preferred type of protected aerial cable terminal.

7. PROTECTED CABLE TERMINAL INSTALLATION

7.1 A protected aerial cable terminal installation should be used for all cable circuits which are extended by circuits of a non-cable type when such extensions exceed 1500 feet in length.

7.2 It is recognized that serious exposures to lightning can exist within the 1500 feet mentioned above, therefore it may be desirable in some situations to provide protectors on extensions less than 1500 feet from the cable terminal.

7.3 If one or more circuits are over 1500 feet in length and require protection, all circuits of the non-cable type connected to the same cable terminal, regardless of their length, should be provided with protector blocks to prevent excessive voltages at the terminal.

7.4 The ground terminal of the protector mounting should always be bonded to the cable sheath to limit the potential difference between the sheath and cable pairs extended by non-cable plant.

7.5 In areas subject to high lightning incidence the ground terminal of the protector at an aerial cable-open wire junction should be grounded at the junction pole if a local ground having a resistance of the same order of magnitude as the cable sheath resistance to ground, or preferably lower, is readily obtainable. This grounding procedure was also discussed in Section 815, Paragraph 2.2 as part of the grounding scheme for cable sheaths.

OPEN WIRE CIRCUIT PROTECTION

CONTENTS

1. GENERAL

1.1 This section describes the various protection measures to be used on open wire telephone circuits. These measures are meant for the protection of subscribers and their property, protection of personnel working on the lines, and the protection of subscriber station equipment, central office equipment, and wooden poles.

2. POWER CONTACT PROTECTORS AND THEIR APPLICATION

2.1 Power contact protectors, Fig. 1, consist of air gap arrester blocks connected between an open wire telephone circuit and ground. The arrester blocks are designed to break down at a value of approximately 3000 volts to ground and, upon breakdown, they possess high current carrying capacity.

2.2 When an open wire telephone circuit equipped with these protectors comes in contact with an electric supply circuit whose voltage to ground exceeds 3000 volts the protector gaps break down and provide a low impedance path to ground for the electric supply system fault current. This provides for rapid deenergization of the electric circuit in the event of a power contact.

2.3 It was stated in Section 805 Paragraph 2.3 that the subscriber station protector fuses should provide reliable clearing of currents at unity power factor with values up to 300 amperes at 3000 volts,

r.m.s.,60 cycles across their terminals. In the event of a power contact with a voltage exceeding 3000 volts to ground, the power contact protector will break down and, with its low impedance discharge path, it will prevent subscriber station protector fuse holdover by limiting the voltage on the station protector and drop wire installation.

2.4 Since these protectors are used to provide a reliable path to ground for electric supply currents in the event of a power contact, and since a further function of these protectors is to reduce the duty on subscriber station protectors, it is evident that in their application the lowest resistance ground connection practicable should be used for proper operation. This condition can usually be well met if the ground terminals of the power contact protectors can be interconnected to the multi-grounded neutral of the electric supply system, if such a system is involved. The requirements given in Section 815 Paragraph 4.2 regarding connections to the vertical ground wire interconnected to the neutral apply for all installations of power contact protectors. If other methods of use for power contact protectors are to be employed, an examination of the available grounding methods should be made by the Engineer.

2.5 Before installing power contact protectors in a telephone system, however, the Borrower's Engineer should investigate the time-current characteristics of the fuses, circuit breakers, and other protective devices installed on the electric supply system to determine if the power contact protectors will provide adequate coordination with these time-current characteristics.

3. INSTALLATION OF POWER CONTACT PROTECTORS ON JOINT USE LINES

3.1 Power contact protectors should be installed on open wire telephone circuits where these circuits are exposed under conditions of conflicting construction (if unavoidable) or joint use to possibilities of contact with electric supply circuits operating at nominal phase to ground voltages in excess of 3000 volts.

3.2 In joint use arrangements power contact protectors should be installed on the circuits occupying the top crossarm of the open wire leads at the poles where the joint use begins and ends and, in addition, at intervals of approximately 20 ohms as specified in Table I for longer joint use arrangements.

TABLE I

TYPE OF CONDUCTOR	INTERVAL IN MILES BETWEEN POWER CONTACT PROTECTORS
104 Copper	4
080 40% Copper Covered Steel	1
104 40% Copper Covered Steel	2
128 40% Copper Covered Steel	3
104 30% Copper Covered Steel	1
128 30% Copper Covered Steel	2
109 Galvanized Steel	0.5
HTL 85	0.5
HTL 135	0.5
HTL 190	0.5

An exception to the requirements given in this paragraph which the Engineer should consider is given below in Paragraph 3.3.

3.3 There are situations, see Fig. 2, where open wire telephone leads are involved in short lengths of joint use with electric supply systems (voltages to ground exceeding 3000 volts) from a point where separate telephone and electric supply lines are used to a subscriber's residence. One power contact protector should be installed on the circuit at the location where the joint use begins, which is usually the point where the telephone leads cross the electric supply lines. The installation of only one power contact protector per circuit is adequate for this type of joint use if the limits given in Table II for crossings are not exceeded. The requirements given below in Paragraphs 4.3 and 4.4 also apply on installations of this type.

4. INSTALLATION OF POWER CONTACT PROTECTORS AT CROSSINGS

4.1 The crossing of electric supply and telephone circuits should preferably be made at a pole jointly occupied by the facilities of both companies.

4.2 Where a crossing of an electric supply circuit of the common multi-grounded neutral type is made at a jointly used pole, power contact protectors should be installed at the crossing on the circuits occupying the top crossarm of the open wire leads, or on a single circuit.

4.3 Power contact protector installations at crossings usually provide a low impedance path for leads exposed to power contacts for an interval on each side of the crossings. For this reason, leads exposed to power contacts at adjacent crossings need not be provided with power contact protectors *if* the same exposed leads to which power contact protectors are attached at protected crossings again appear as exposed leads at adjacent crossings within intervals of approximately 10 ohms as specified in Table II.

TABLE II

TYPE OF CONDUCTOR	INTERVAL IN MILES FROM CROSSING EQUIPPED WITH POWER CONTACT PROTECTORS
104 Copper	2
080 40% Copper Covered Steel	0.5
104 40% Copper Covered Steel	1
128 40% Copper Covered Steel	1.5
104 30% Copper Covered Steel	0.5
128 30% Copper Covered Steel	1
109 Galvanized Steel	0.25
HTL 85	0.25
HTL 135	0.25
HTL 190	0.25

4.4 If however, leads other than those attached to power contact protectors at protected crossings appear as exposed leads at adjacent crossings, power contact protectors must be installed on these exposed leads. The requirements given in Section 815, Paragraph 4.2 regarding connection to the vertical ground wire and neutral apply for the installation of power contact protectors at joint pole crossings.

4.5 With proper attention given to the mechanical design of a jointly used pole at a crossing, and with power contact protectors installed as above, the situation from the standpoint of the telephone plant is more favorable than a crossing made on separate poles since the possibility of contact is decreased and a good ground connection for the power contact protectors is usually established.

4.6 The use of power contact protectors at the crossing will frequently make it unnecessary to adopt further precautions even if the nominal electric supply circuit line voltage is somewhat in excess of the 8700 volts to ground mentioned in Section 801, Paragraph 7.2 in connection with joint use. The question of how high the line voltage may be before additional protective measures become necessary cannot be answered definitely at present. It involves the capabilities of power contact protectors of present design and particularly the availability of low resistance grounds at the crossing. It may be said, however, that at crossings where the electric circuit voltage is of the order of 25,000 volts or higher, the Borrower's Engineer should determine what protection measures, if any, need be taken. This is the case whether the electric circuit is classified as transmission circuit or as a distribution circuit. In general, the higher the voltage of the electric system the less probability of a power contact due to the increased strength and clearances required for the electric system. This is particularly true for electrical transmission systems.

4.7 No comparatively effective protection arrangements are available for crossings within spans, and it will be necessary to rely upon adequate construction at the crossing. As an alternative, it may be practicable to protect crossings within spans by means of a power contact protector installation at a nearby point where a common multi-grounded neutral is available. Crossings made by means of underground cable dips in open wire leads are discussed as part of cable protection in Section 815, Paragraph 5.2.

5. DRAINAGE UNITS

5.1 Drainage units, Fig. 3, are used on open wire telephone circuits to limit voltages due to electric induction (See Section 801, Paragraph 4) from paralleling electric systems. They usually consist of balanced resistor-capacitor or inductor-capacitor networks connected from each side of the line to ground. (With the inductor-capacitor type an additional "tuning" inductor is connected between the junction of the two networks and ground.) Air gap protector blocks are normally used to protect such units from high potentials due to lightning and other causes.

5.2 Drainage units of the inductor-capacitor type present a low impedance to ground for 60 ± 10 c.p.s. and a relatively high impedance across the line. This provides effective drainage without appreciable transmission or ringing loss on systems using ringing frequencies of 30 c.p.s. or lower. At frequencies within the range of 50 to 70 c.p.s. the impedance of tuned drainage units is somewhat comparable to that of a fairly low impedance ringer. The shunting effect of the drainage units to ringers responding to selected frequencies within the range of 50 to 70 c.p.s. may be sufficient to prevent satisfactory ringing on long loops. Therefore ringers in this frequency range should be located as near to the central office as practicable.

6. INSTALLATION OF DRAINAGE UNITS

6.1 The installation of drainage units is not usually necessary on telephone circuits involved in joint use with or paralleling three phase multi-grounded neutral electric supply systems.

6.2 Western Electric Company 108A tuned drainage units, or the equivalent, should be installed on telephone leads consisting of a single circuit if this lead is involved in joint use with the same single phase multi-grounded neutral electric supply circuit (operating at 6900 - 8700 volts to ground) for a distance of 10 miles or more. The drainage units should be installed on the open wire lead at a point 3 miles from the beginning of the joint use arrangement, and at intervals of 7 miles from this point for the remainder of the joint use. The ground connection for the drainage units should be made

to a driven ground rod, even though the multi-grounded neutral is available.

6.3 In the case of joint use construction with crossarms containing two to five circuits, Western Electric Company #108A drainage units, or the equivalent, should be installed on the two circuits subjected to the greatest exposure throughout the joint use section, if the joint use exceeds 13 miles in length. Drainage units should be installed on each of the two selected circuits at a point 3 miles from the beginning of the joint use, and at intervals of 10 miles from this point to the end of the joint use section. The increased spacing interval for this situation is possible because there is less voltage induced in all circuits on the lead when two circuits are drained as compared with the voltage induced when only one circuit is drained.

6.4 If, at a later date, the single circuit previously mentioned in Paragraph 6.2 is placed on a multi-circuit crossarm when additional circuits are added along the route, the spacing of the drainage units of this pair should be made to conform with the 10 mile interval as given in the above paragraph.

6.5 Additional circuits added to a crossarm which already is carrying two circuits equipped with drainage units ordinarily require no drainage units. Likewise, circuits on crossarms beneath the top crossarm ordinarily require no drainage units.

6.6 For exposures to the same single phase electric supply line (operating at 6900 - 8700 volts to ground) in excess of 10 miles and with roadway separations of less than 35 feet Western Electric Company #104A drainage units, or the equivalent, should be installed at 10 mile intervals. The first unit should be installed 10 miles from the beginning of the exposure. Drainage should be provided on not more than two circuits per lead. The circuits selected for the installation should be those subjected to the greatest exposure.

6.7 If the roadway separation is greater than 35 feet no drainage units should ordinarily be used.

6.8 If unexpected difficulties are encountered for any of the above situations, additional measures of mitigation may be needed.

7. LIGHTNING PROTECTION WIRES

7.1 Lightning protection wires may be necessary to prevent splitting of wood poles in certain areas of high lightning incidence. Generally, installations should be made at approximately every fourth telephone company pole where this type of protection is needed. A study of local conditions should be made by the Borrower's Engineer to

determine to what extent this protection is required.

7.2 This form of pole protection consists of a wire stapled from the top of the pole to a point near the ground.

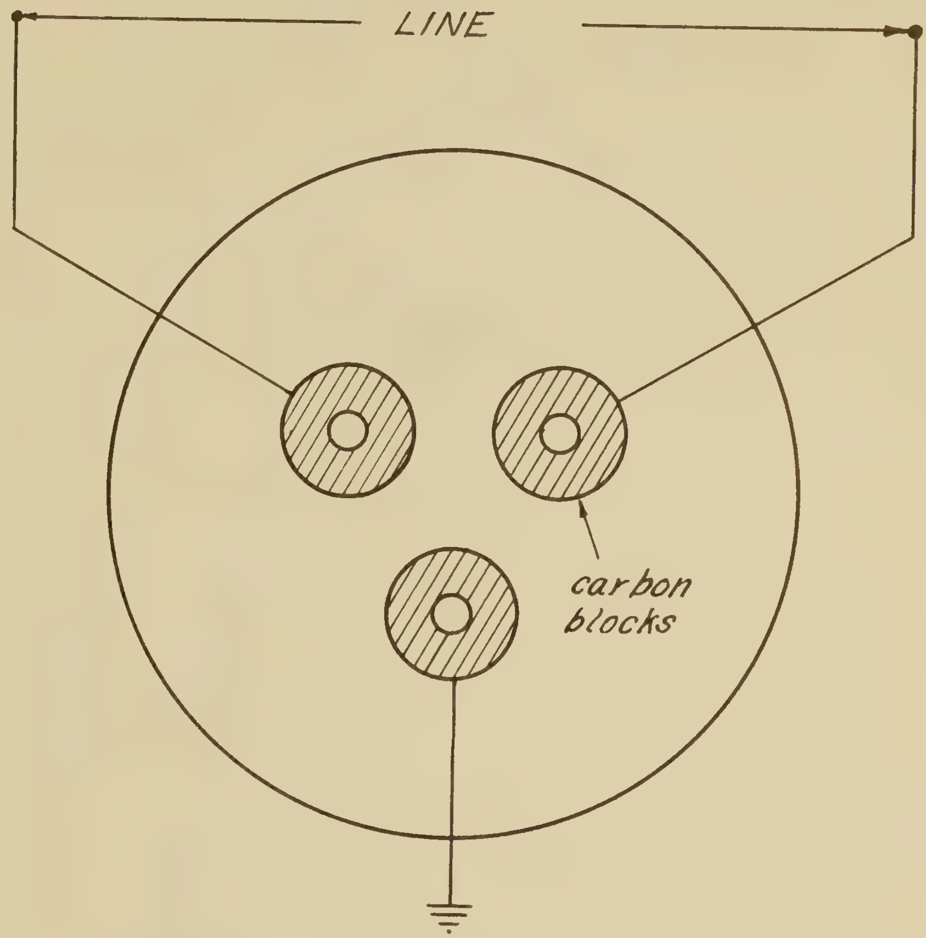


Fig. 1 Power Contact Protector

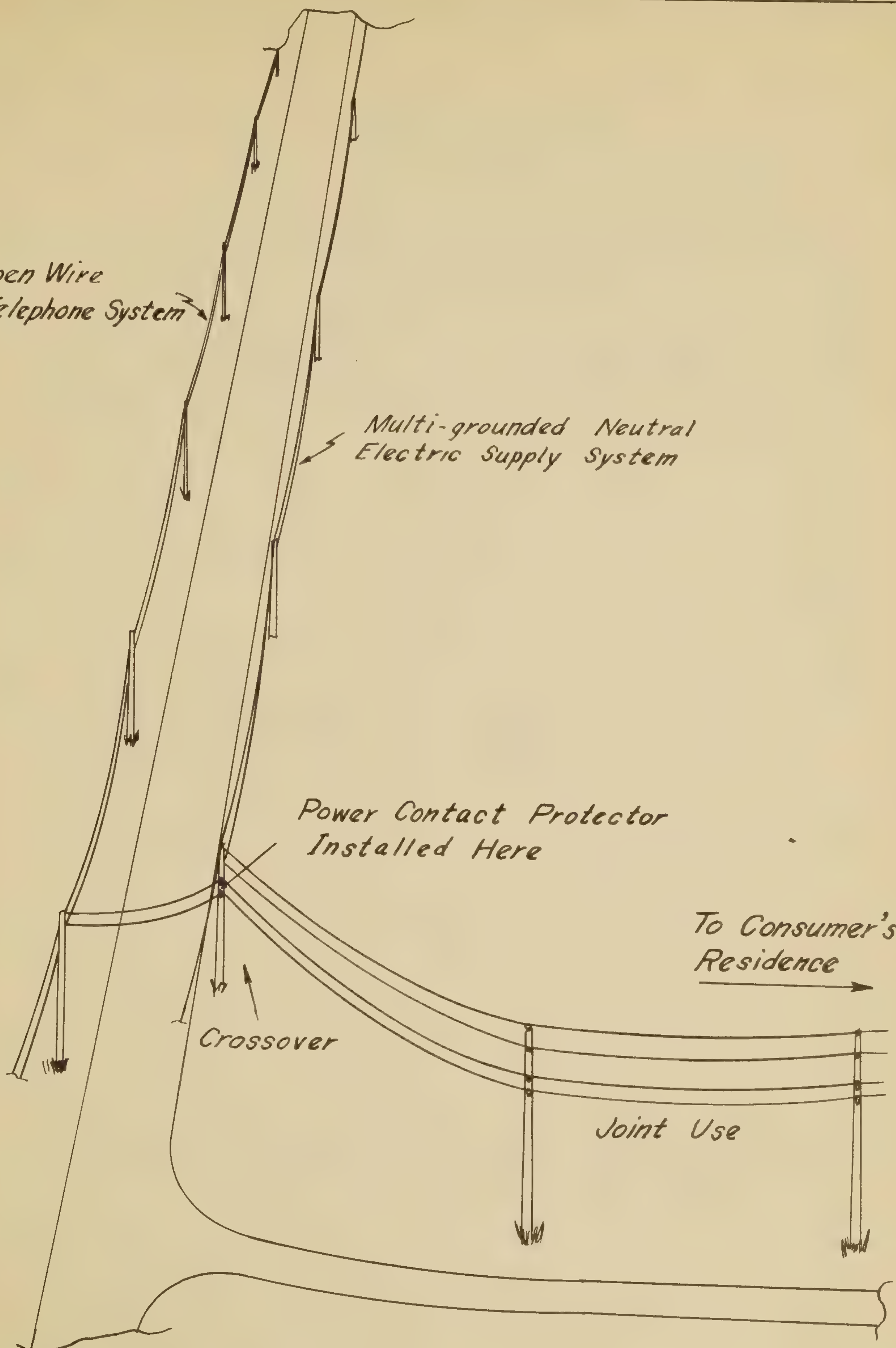


Fig. 2 Short Length of Joint Use.

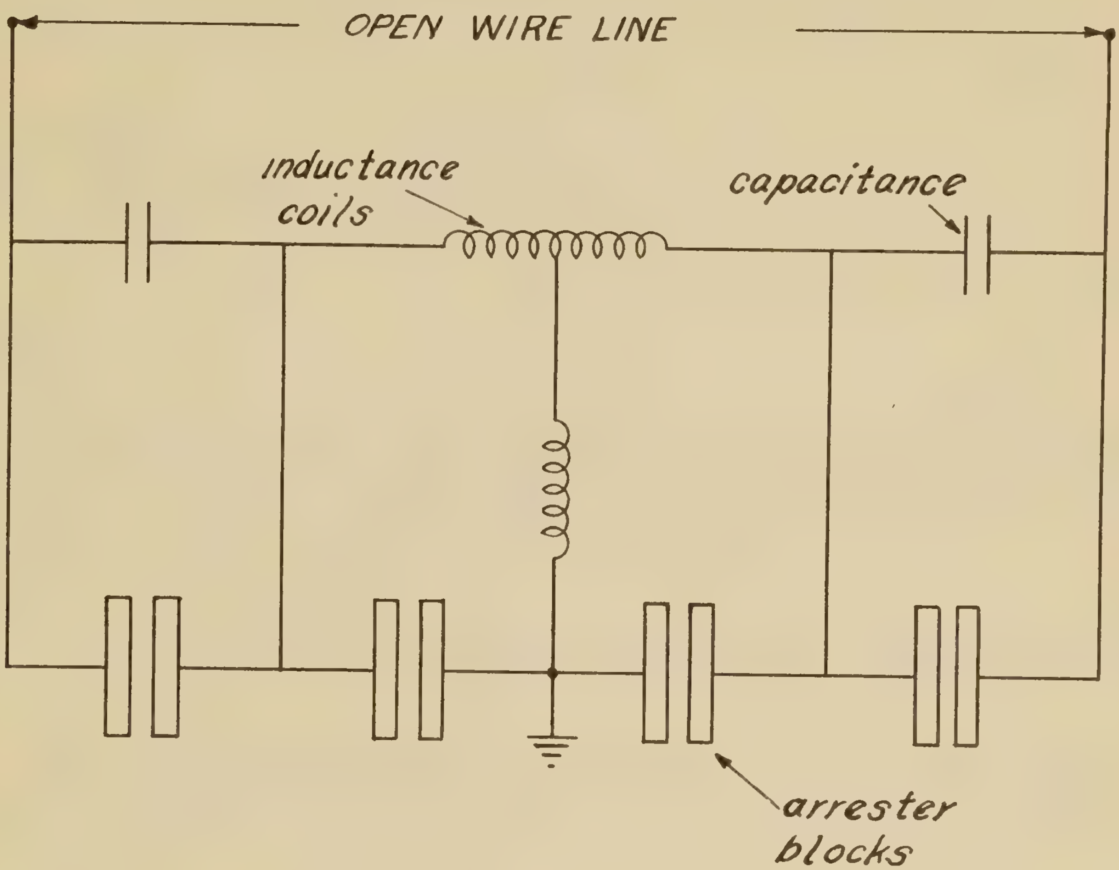


Fig. 3 Typical Tuned Drainage Unit.

UNUSUAL SITUATIONS REQUIRING PROTECTION

CONTENTS

1. GENERAL

1.1 This section lists unusual situations which may be encountered in protection schemes. In any of these situations a study of the factors involved should be made and the appropriate protection scheme selected. A few of the unusual situations listed in Section 801, Paragraph 7 are repeated below:

(a) Long parallels at close separation with electric supply system circuits with operating voltages in excess of 25,000 volts to ground.

(b) Joint use with electric supply systems of the multi-grounded neutral type with operating voltages exceeding 8700 volts to ground.

(c) Joint use with electric supply systems of the non-multi-grounded neutral type with circuit voltages exceeding 5000 volts.

(d) Telephone stations installed in power stations or substations.

(e) Areas of unusually high lightning incidence and high earth resistivity which require devices or protective measures in addition to or different from those listed previously. Likewise, in areas where lightning incidence is negligible or where extensive underground plant is involved, the protective devices required should normally be somewhat less than those described.

1.2 In the following paragraphs several special protection devices which may be applicable in some of the unusual situations stated above are briefly described.

2. SHORT CIRCUITING RELAY PROTECTORS

2.1 Short circuiting relay protectors may be used on important open wire telephone circuits where faults on paralleling power lines may be a frequent source of high energy interference. These devices short-circuit the protector blocks connected from the telephone wires to ground - these protector blocks being component parts of the relay protector. Operation of the protector blocks due to a power fault reduces the telephone line voltage to ground and, by short-circuiting the blocks, the relays prevent their permanent grounding. The relay protectors are available for protection of one circuit or a group of circuits. Their use is not common, but they should receive consideration in certain instances where special protective measures have to be taken to reduce the effects of high magnetic induction.

3. NEUTRALIZING TRANSFORMERS

3.1 Neutralizing transformers should be used where telephone circuits, particularly circuits for relaying, remote control, etc., serve large power stations or substations, although they have other applications as well. In the event of a ground fault near the power station or substation the transformer will prevent the reverse breakdown of the arrester blocks from high ground potentials, thus assuring uninterrupted service over the telephone circuits at a time when continuous operation is essential. The prevention of operation of the telephone protector blocks for the above situation safeguards telephone circuits at remote points by reducing to low values the voltage impressed upon connected telephone circuits at the power station.

4. OTHER SPECIAL DEVICES

4.1 Other special protective devices having very limited application on telephone plant include isolating transformers and explosion-proof subsets.

SUMMARY OF UNITS USED IN PROTECTION SYSTEMS

CONTENTS

1. SUBSCRIBER STATION PROTECTORS

1.1 Unit P1-1

1.11 The P1-1 unit consists of an outdoor station protector, a ground rod, and a bond to an electric system ground.

1.12 This assembly should be used where the electric supply system at the premises is other than the common multi-grounded neutral type and an underground water or gas piping system does not exist at the premises. For additional information see Section 805, paragraphs 4.3 and 5.1.

1.2 Unit P2-1

1.21 The P2-1 unit consists of an outdoor station protector and a ground to a piping system.

1.22 This assembly should be used where either a common multi-grounded neutral electric supply system or other types of electric supply systems are connected to an extensive underground water or gas piping system at the premises. For additional information see Section 805, paragraphs 4.2 and 4.3.

1.3 Unit P2-1A

1.31 The P2-1A unit consists of an outdoor station protector and a bond to a common multi-grounded neutral electric supply system ground at the premises.

1.32 This assembly should be used where the common multi-grounded neutral of the electric supply system is grounded at the premises by means of a driven ground rod. For additional information see Section 805, paragraph 4.2.

2. AERIAL CABLES AND TERMINALS

2.1 Unit PG2-11
Unit PG2-16
Unit PG2-26
Unit PG4-11
Unit PG4-16
Unit PG4-26

2.11 These units consist of air gap lightning arresters, binding posts and cable stub as an integral part of the distribution terminal.

2.12 These assemblies are the preferred type of protected cable terminals and should be used extensively for new cable installations requiring protected terminals. For additional information see Section 815, paragraphs 6.1, 6.2 and 7.2 - 7.5.

2.2 Unit PM2A

2.21 The PM2A unit consists of a bond between the aerial cable and the common multi-grounded neutral of an electric supply system.

2.22 This assembly should be used in joint use construction and at joint pole crossings. For additional information see Section 815, paragraphs 4.1, 4.2 and 5.1.

3. LIGHTNING ARRESTERS

3.1 Unit P3-1

3.11 The P3-1 unit consists of a single pair lightning arrester with jumpers and ground wire.

3.12 This assembly should be used in situations where only one or two circuits require protection and enter an unprotected aerial cable terminal. If more than two pairs require protection, the preferred type aerial cable terminal (Section 815, paragraph

6.2), or five pair lightning arrester assemblies in conjunction with unprotected aerial cable terminals, should be used. For additional information see Section 815, paragraphs 6.1, 6.3 and 7.1 - 7.5.

3.2 Unit P3-5

3.21 The P3-5 unit consists of five pair lightning arresters with jumpers and ground wire.

3.22 This assembly should be used in situations where three to fifteen circuits require protection and enter an unprotected aerial cable terminal. For additional information see Section 815, paragraphs 6.1, 6.3 and 7.1 - 7.5.

3.3 Unit P3-5 with PM2

3.31 This unit consists of five pair lightning arresters with ground wire and ground rod.

3.32 This assembly should sometimes be placed on the open wire leads within one-half mile of the aerial cable terminal to reduce lightning surges on the open wire leads before they reach the cable terminal. For additional information see Section 815, paragraph 2.3.

4. POWER CONTACT PROTECTORS

4.1 Unit P4-1

4.11 The P4-1 unit consists of a power contact protector with jumpers and hardware.

4.12 This assembly should be installed at particular intervals on open wire circuits which are exposed to power contacts. These exposures could occur in joint use arrangements and at crossings. For additional information see Section 820, paragraphs 2.1 - 4.7.

5. DRAINAGE UNITS

5.1 Unit P5-1

5.11 The P5-1 unit consists of drainage units of the capacitor-resistor type with jumpers and lightning arresters. This unit is used for reducing the electrically induced voltage on two open wire circuits.

5.12 This assembly should be installed in accordance with the instructions given in Section 815, paragraphs 5.1, 6.6 and 6.7.

5.2 Unit P6-1

5.21 The P6-1 unit consists of a drainage unit of the inductor-capacitor type with jumpers and lightning arresters. This unit is used for reducing the electrically induced voltage on one open wire circuit.

5.22 This assembly should be installed in accordance with the instructions given in Section 815, paragraphs 5.1, 5.2 and 6.1 - 6.5.

6. POLE LIGHTNING PROTECTION

6.1 Unit PM-1

6.11 The PM-1 unit consists of wire and staples.

6.12 This assembly is used to prevent splitting of wood poles in certain areas of high lightning incidence. Installations should be made on telephone company poles at approximately every fourth pole in exposed areas. For additional information see Section 820, paragraphs 7.1 and 7.2.

7. FURTHER CONSIDERATIONS IN SYSTEM PROTECTION

7.1 In the Detailed Requirements for Central Office Equipment, the Borrower's Engineer should specify which type of mainframe (A or B) is required and should indicate the type of protective equipment to be furnished. For additional information see Section 810, Paragraphs 2.1, 2.2, 3.1 and 4.1.

7.2 In the Cable Plant Layout, the Engineer should specify the installation of small gauge cable sections for central office protection at the following locations:

7.21 Junctions of underground or buried cable from the central office with aerial cable.

7.22 Junctions of underground or buried cable from the central office with open wire lines.

7.23 Where the central office is entered by means of aerial cable.

For additional information see Section 810, Paragraphs 5.1 - 5.5.

7.3 The Engineer should consider the following types of central office ground connections and select those applicable to the particular situation:

7.31 Installation of auxiliary driven ground electrodes.

7.32 Auxiliary driven ground electrodes together with common multi-grounded neutral of the electric supply system serving the central office.

7.33 Auxiliary driven ground electrodes together with public water or gas system at the central office.

7.34 Auxiliary driven ground electrodes bonded to the electric supply system ground if the electric supply system serving the central office is other than the common multi-grounded neutral system.

For additional information see Section 810, Paragraphs 6.1 - 7.5.

7.4 In the Plans and Specifications, the Engineer should also consider the following:

7.41 Bonding and grounding of aerial cable sheaths. For additional information see Section 815, Paragraphs 2.1 - 5.1.

7.42 Bonding of underground sheaths at manholes. For additional information see Section 815, Paragraph 3.6.

7.43 Advisability of grounding aerial cable sheaths at open wire end of cable run if multi-grounded neutral is not available. For additional information see Section 815, Paragraph 2.2.

7.44 Crossing of railroads, and so forth, by means of underground cable dips. For additional information see Section 815, Paragraphs 5.2 and 5.3.